CAN Signal Improvement

CAN FD (flexible data rate) was introduced as an extension of classical HS-CAN that enabled more data to be exchanged at faster bit rates. While clearly boosting the throughput of CAN, the accelerated bit rates created new signal integrity problems, significantly limiting its application in the topologies that car makers ultimately required. New CAN signal improvement capability (SIC) transceivers will remove these limitations and accelerate CAN FD beyond what was previously possible, helping open up new possibilities for this technology.

CAN FD: Accelerating to 2 Mbit/s

Getting faster bit rates through a CAN network is not a new challenge. Communication bandwidth is always in demand. As many automotive networks have evolved over time, they have slowly reached their bandwidth capacity. The maximum bit rate a CAN network can reliably operate at has been traditionally limited by the "loop delay," a timing parameter defined in the ISO11898-2 standard. Essentially, it equated to a simple principle: faster bit rates enforce smaller networks. Specifically, a shorter maximum distance between any two nodes.

This limit derives from the arbitration phase, where all nodes need to correctly receive every other nodes' signal to collectively agree on which has priority to send. CAN FD, by comparison, could accelerate to higher bit rates by only doing so in the data phase of communication, when arbitration has completed and there is just one node sending. The "loop delay" requirement no longer applies here, although it does still apply unchanged during the arbitration phase of CAN FD. As a result, every CAN FD network has two defined bit rates: the bit rate during the arbitration phase (typically similar bit rates to previous HS-CAN networks) and the data phase, or "fast phase," bit rate, when the payload is sent and when faster bit rates can be achieved.

While CAN FD was defined up to 5 Mbit/s in the fast phase in the ISO11898-2:2016, quickly a new speed limit was encountered when networks were evaluated at these higher bit rates. This time, it was achieving a stable signal during the recessive bit, which became distorted due to two topology effects: signal ringing, created by unterminated stubs (or branches) in the wiring harness, and signal plateaus, created by a lower characteristic cable impedance. These both disturbed the signal at the beginning of the recessive bit and delayed it from becoming stable below a differential voltage of 0.5 V. This 0.5 V is the minimum receiver threshhold (defined in the ISO11898-2:2016) as the point at which all transceivers must interpret the signal as recessive.

These effects were not new creations of CAN FD and already existed in traditional HS-CAN networks. However, the bit rate in the fast phase meant bit times were significantly shorter. Therefore, the effects, which were normally small artefacts way ahead of the sample point, now became significant roadblocks to reliable communication.

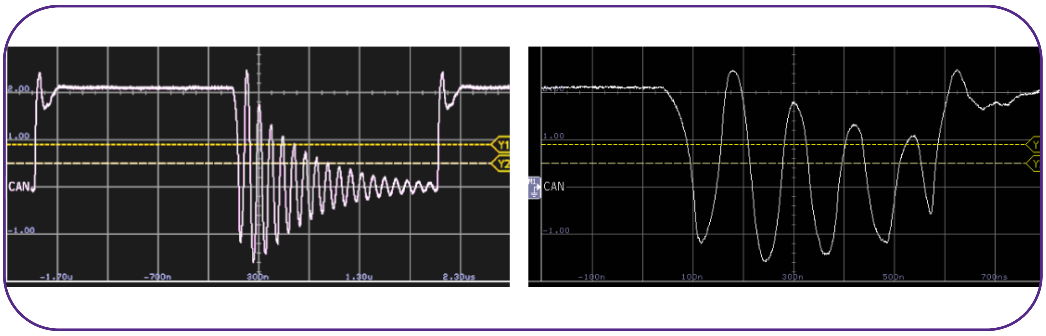

Figure 1: Signal ringing examples at 500 Kbit/s (left) and 2 Mbit/s (right). The horizontal lines show the minimum and maximum receiver thresholds. To guarantee reliable communication, the signal must be stable underneath the minimum receiver threshold by the sample point, typically around 70-80% of the bit time. In the 2 Mbit/s example, the signal still peaks above this limit, preventing reliable communication to occur.

To mitigate these effects, network architects had to limit the complexity of their topologies, by avoiding long, unterminated stubs and opting for a reduced number of nodes arranged in a typically linear (or daisy-chain) network. Though this approach guaranteed communication, it came with several side-effects: an increase in network branches leading to more complex gateways, more connectors, more cabling being routed through a vehicle and more complex installation and test during vehicle production. A simple illustration of this would be routing a cable to a roof module. With a linear topology, the cable now needs to both stretch 1 to 2 meters up to the roof, and then back down again, instead of just having a one-way stub. This adds more cost and weight to the cable harness. Even with these mitigations however, CAN FD became effectively limited to 2 Mbit/s communication outside of point-to-point connections.

CAN Signal Improvement Capability

The problem of controlling the signal during recessive bit is what led to the development of CAN signal improvement. The approach is to actively bring the recessive signal to below the minimum recessive threshold level of 0.5 V, instead of just releasing the dominant signal as conventional transceivers do.

When actively driving recessive, however, it is essential that all the mechanics of the existing CAN and CAN FD protocols shall be fully guaranteed, as especially arbitration, frame acknowledgement and error handling rely on the overwriting of recessive bits with dominant to work. By actively driving recessive, it needs to be guaranteed, in all worst cases, that a recessive bit may be reliably overwritten and so the CAN and CAN FD protocols still operate.

NXP's CAN signal improvement technology is a highly robust and high-performance solution, enabling both much higher bit rates than conventional transceivers, while delivering the reliability of communication that conventional transceiver have been delivering for years. NXP's solution is based on the TXD input, which is both reliable and allows a significantly faster activation time, since this triggers the signal improvement even before the internal propagation delay of the transceiver. Faster activation of the signal improvement means ringing is controlled earlier in the bit time, guaranteeing communication in networks with more severe ringing (thus more complex topologies) or in a network with even faster bit rates. System predictability is straightforward since there is only one sender applying signal improvement. This avoids having possibilities for unpredictable interactions between nodes and since each node manages their own signal, should any node lose power, its impact would be limited only to that node.

Additional, NXP's CAN signal improvement technology is fully backwards compatible with conventional HS-CAN transceivers, and fully compliant to the ISO11898-2:2016 specification. This compatibility and compliance help enable adoption in an application by simply replacing the existing transceiver and helps the vehicle manufacturer avoid making two versions of a module: one with and one without CAN signal improvement technology. Should a CAN Signal Improvement transceiver be used in a legacy network, the only side effect will be an improved ringing performance when that node transmits.

Transceiver Symmetry Explained

The final standout feature of NXP's solution is its very accurate transceiver symmetry. The transceiver symmetry is highly relevant to the overall capabilities of a CAN FD network. Simply, it defines how much timing deviation is seen on successive bit edges from TXD to the CAN bus, and from the bus to RXD. This is relevant because all

CAN controllers synchronize on a dominant bit transition, and any transceiver asymmetry will introduce potential timing differences for when nodes make their sample point. Since guaranteeing reliable communication relies on a signal being stable at the sample point, it is important to calculate when the earliest sample point may occur, including these deviations, and assess the signal stability at that moment. Before that time, no sample point will ever occur, so signal distortions are no problem. This can be referred to as the "allowable ringing time," shown in Figure 2.

Transceiver symmetry is a significant component in the total asymmetry calculation within a network. Thus, tightening the symmetry specification means less possible spread. The earliest sample point will appear relatively later, too. This in turn increases the allowable ringing time before that earliest sample point. Unlike the ISO11898-2:2016, which defined symmetry values for 2 Mbit/s and 5 Mbit/s, NXP's CAN signal improvement transceivers defines bit-rate independent values with a much tighter symmetry specification. This enables CAN FD to tolerate significantly more ringing, and also allows significantly shorter bit times, extending the maximum bit rate CAN FD can operate to beyond 10 Mbit/s.

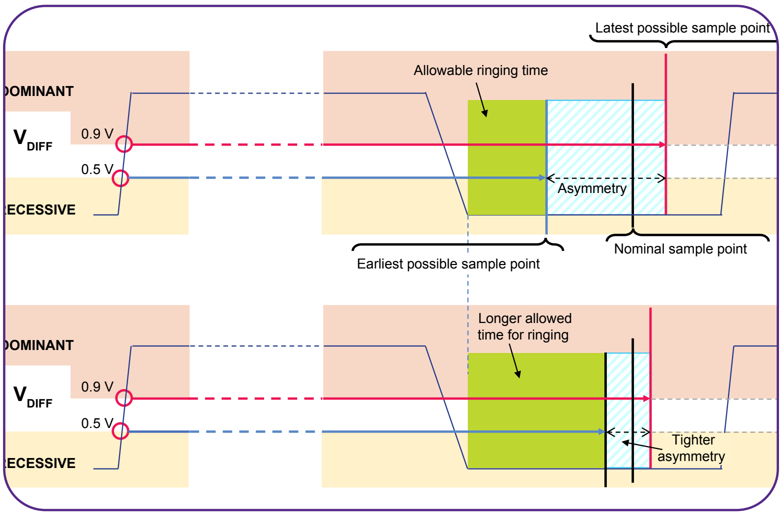

Figure 2: A tighter asymmetry means the sample point will drift less in time. This in turn allows more time for ringing to occur without affecting network communication.

NXP's CAN SIC Technology

NXP has played a key role with other industry partners in the development of this technology, now defined in the CiA601-4 v2.0.0 specification. This solution has been extensively evaluated globally by car makers and demonstrated to reliably operate complex networks beyond 5 Mbit/s. At 2 Mbit/s, it significantly boosts potential network topology dimensions and our experience broadly shows a topology validated at 500 Kbit/s can be operated at 2 Mbit/s. An additional advantage of the NXP CAN SIC solution is that it is baud-rate independent, with one device able to serve any bit rate. NXP is now sampling this technology and we expect the first vehicles using this technology to be on the road in 2020.

CAN signal improvement really extends what is feasible with CAN FD and 5 Mbit/s becomes a definite reality for car makers to consider in their future technology choices. With vehicle network architectures undergoing major changes in the next generations of vehicles, this positions CAN FD as a relevant and meaningful technology to consider.

Although signal improvement can theoretically go way beyond 5 Mbit/s, accelerating the fast phase to even higher bit rates comes with diminishing returns, given the arbitration phase remains unchanged. Therefore, there is a natural link from signal improvement technology towards CAN XL, which intends to significantly increase the payloads and remove limitations in the current CAN FD protocol that would enable more physical layer improvements of the signals. That technology step will require new protocol controllers in the microcontroller—something not required with signal Improvement transceivers of today—but with this promising technology targeting 10 Mbit/s communication and 2 KB frames, it extends the potential and relevance for CAN even further within new vehicle networks.

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